BIOLOGY AND IMMATURE STAGES OF *DIRRHAGOFARSUS LEWISI*, A SPECIES NEW TO THE UNITED STATES (COLEOPTERA, EUCNEMIDAE)

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Abstract

Dirrhagofarsus lewisi, accidentally introduced from Japan, was found boring in a fallen, dead beech tree, *Fagus grandifolia*, in Baltimore, Maryland, in 1976. The genus is referred to an existing North American determination key, and the life history, pupa, and larva of the species are described. Morphological adaptations of the larva are discussed.

Introduction

Information in this article actually started to accumulate in March 1975 when a large beech tree, *Fagus grandifolia* Ehrhart, was blown down in Leakin Park, Baltimore, Maryland. The tree had broken off at ground level, and the trunk, about 1 m in diameter, had a large longitudinal split at the base exposing about 1 square meter of sapwood and heartwood. It had fallen in a ravine beside a small stream, almost completely shaded by the surrounding forest, in an undergrowth primarily of spicebush, *Lindera benzoin* (L.)Bl. On 4 March 1976 the tree was examined by the senior author to find larvae and pupae resulting from oviposition by various insect species during the previous summer. Most obvious at this time was the exposed sapwood which had been recently pecked by woodpeckers. Food for insectivorous birds is very scarce in winter, and woodpecker holes are a reliable indication of the presence of live insects. Several areas of wood adjacent to woodpecker damaged areas were chopped away, exposing numerous oval chambers about 6 mm below the surface. Each chamber contained an elongate, white larva lying in a U-position. At first these chambers were thought to be pupal cells, but, strangely, there were no entrance or exit holes leading to or from these excavations. Samples of wood were taken to the laboratory where smaller pieces were placed in open rearing jars and larger pieces in plastic bags to retain moisture. The larvae were identified as Eucnemidae but were not the expected most common local species, *Melasis pectinicornis* Melsheimer or *Isorhipis ruficornis* (Say). Adults failed to emerge from the smaller sample in the jars because the wood dried out too quickly, but on April 12 adults appeared in the plastic bags. Subsequent investigations of the adults revealed that they are *Dirrhagofarsus lewisi* (Fleutiaux), a species not previously recorded from North America.

At present *Dirrhagofarsus lewisi* is known in the United States only from Leakin Park, Baltimore, Maryland. Sixty-eight (68) adults plus several larvae and pupae were collected from the same beech tree between 4-III-76 and 11-VIII-76 by the senior author and J. F. Cavey. Outside the United

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States *D. lewisi* had been recorded from all major islands of Japan and from Formosa.

Details of the life history of this species in Maryland are given below so that comparisons can be made with biological notes on other North American eucnemids given by Mosher (1919) and Van Horn (1909). The life history of *D. lewisi* in Japan is unknown. The immature stages of *D. lewisi,* previously undescribed, are herein described and illustrated.

A brief history of the taxon *Dirrhagofarsus lewisi* in the literature is as follows: Fleutiaux (1901:358) described *Microrhagus lewisi* from Central Japan; Fleutiaux (1922:308, 313) transferred *lewisi* to *Dirrhagus* (sic) and included it in a key to the species of Japan; Fleutiaux (1935:15) described the genus *Dirrhagofarsus* with *Microrhagus lewisi* Fleutiaux as the type-species by monotypy; Hisamatsu (1955:100) said the species occurs on the major Japanese islands and gave its detailed distribution on Shikoku; Cobos (1965:398) included *Dirrhagofarsus* in a worldwide key to the Dirrhagitae (sic).

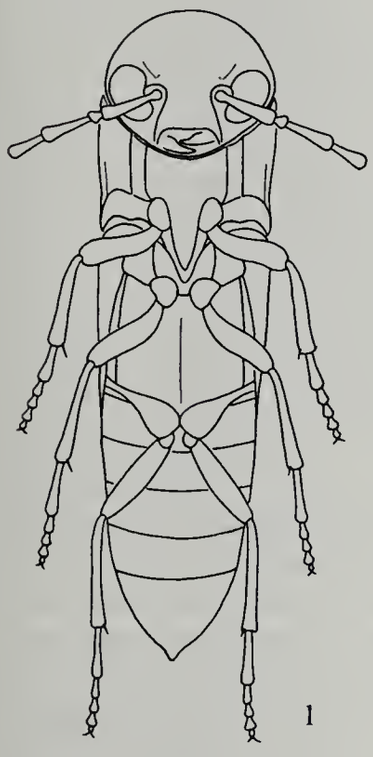
In North America *Dirrhagofarsus* most closely resembles *Dirhagus.* Outstanding in *Dirrhagofarsus* (figs. 1-2) are the raised, asperate elytral apices and the two straight interocular carinae on the front of the head, one near the margin of each eye. *Dirhagus* has the elytral apices simply tapering and the interocular carinae lacking. In general appearance *Dirrhagofarsus* most closely resembles *Dirhagus impressus* (Bonvouloir) and *D. wrighti* Knull in being light-brown, large species, 5-11 mm long; other species of *Dirhagus* are black and usually not more than 5 mm long.

The genus *Dirrhagofarsus* would be determined as *Dirhagus* in Arnett's (1968:522) key to the eucnemid genera of North America. Couplets 11-14 of that key should be modified to accommodate *Dirrhagofarsus.*

11(4).	Metepisternum distinctly triangular, and elytral apices evenly rounded, not asperate	*Adelothyreus*
11′.	Metepisternum linear, subparallel sided, or if triangular then elytral apices strongly asperate and elevated	12
12(11).	Antennae with second segment small, third elongate	13
12′.	Antennae with second and third segments small, moniliform	*Entomophthalmus*
13(12).	Posterior coxal plates dilated medially	14
13′.	Posterior coxal plates not dilated medially, their anterior and posterior margins subparallel	*Rhagomicrus*
14(13).	Juxtasutural groove with lateral borders distinct and margined throughout	14A
14′.	Juxtasutural groove with lateral borders obscure and without margins posteriorly	*Arrhipis*
14A(14).	Elytral apices strongly asperate, elevated, and projecting on first intervals	*Dirrhagofarsus*
14A′.	Elytral apices evenly rounded, not asperate, elevated, or projecting on first interval	*Dirhagus*

Descriptions of Immature Stages

PUPA: Slender, approximately 10-12 mm long (fig. 3). Head (fig. 4) with 3 pairs of gibbosities, a pair on frons, a larger pair on vertex, and a gibbosity on dorsal part of each eye and extending onto vertex; with sparse, fine, short, curved setae on each gibbosity. Antenna (fig. 5) with each article, except 11th, having transverse gibbosities on lateral surface near apex, each gibbosity with dense, minute, dark reddish setae. Pronotum and wing sheaths with fine, short, curved setae that are denser near lateral borders. Abdomen narrowly oval; in dorsal view terga 1-6 with lateral borders excurved, broadest posteriorly, in cross-section border moderately sharp, not heavily sclerotized or darkened; tergum 7 with lateral borders evenly excurved; tergum 8 with lateral borders excurved and converging posteriorly; tergum 9 narrow, short, posteriorly rounded and with narrow fingerlike process arising from median surface and covered with dense, minute, dark-reddish setae; spiracles circular, their posterior borders raised, on terga 2-7 on anterolateral corner, spiracles on 1 and 8 on lateral surface, not visible in dorsal view; setae long, slender on lateral borders, short slender on posterior borders of terga.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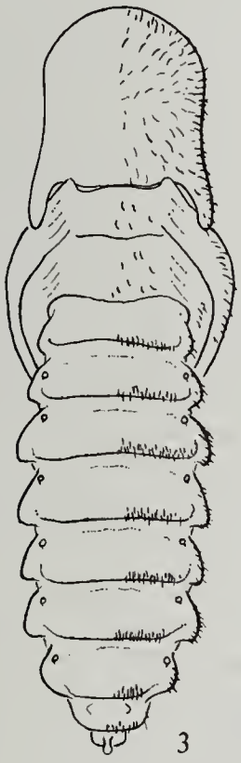
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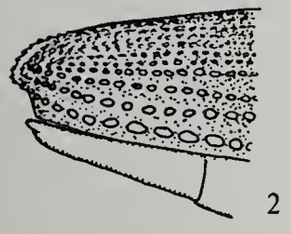
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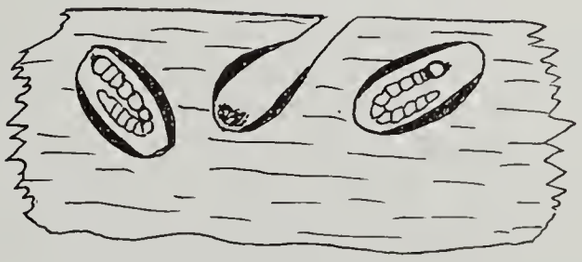
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Figs. 1-6. *Dirrhagofarsus lewisi*: 1) adult, ventral view; 2) adult, apex of elytra and abdomen, lateral view; 3) pupa, dorsal view; 4) pupa, head, anterior view; 5) pupa, apex of antenna; 6) larval cells in wood.

LARVA: Slender, elongate; maximum length, 16 mm; maximum width, 2 mm; without legs, ocelli, and setae; without sutures on or between thoracic and abdominal terga, sterna, or lateral areas, the segments delimited only by simple, weak intersegmental constrictions. Head (figs. 7-8) small, not narrowed or rounded posteriorly, deeply embedded in prothorax, without cervical membrane; anteriorly narrowed, lateral borders and dorsal and ventral surfaces converging anteriorly; head capsule without sutures and without definable sclerites; mouth frame (complete anterior border of head capsule) heavily sclerotized to support mandibles; dorsally (fig. 8) with very large plate that covers almost whole surface and continues around lateral surface; ventrally (fig. 7) with large plate; each plate with a few very large, greatly raised, irregular, longitudinal carinae; mouth frame dorsally broadly triangular, anterior border irregular, with median apex between mandibles acute, clypeus and labrum not definable; mouth frame ventrally transverse, with median borders between mandibles truncate, gula and base of labium not definable. Antennae (fig. 9) lateral, very near mouthframe, inserted in nonsclerotized areas, with wide crescentic sclerite posterodorsal to point of insertion; antenna very small, 1st article relatively long, length twice width, with tiny apical sensorium, 2nd article small, length about one-third length of 1st article, with minute sensorium and 2 minute setae on apex. Mandibles (figs. 12, 13) short, wider than long, tapered laterally, obliquely oriented with anterolateral cutting edge; anterolateral surface of each mandible evenly convex on dorsal edge and with 2 large acute teeth in early instars (fig. 13) or 2 large blunt teeth in late instars (fig. 12) and 1 small blunt tooth on ventral edge; medial surface (facing other mandible) almost flat, its anterior border sharp, knifelike, and continuous with first tooth on apical surface; posterodorsal edge with large acetabulum at midwidth; posteroventral edge with small acetabulum at lateral third; small tendon and muscle attached medially and large tendon and muscle attached laterally. Maxillae absent. Labium (fig. 10) very small, very weakly sclerotized, with 3 segments of equal lengths, apex rounded and with 2 sensillae; labial palpus slender, with 3 articles, apex rounded and with 2 sensillae. Prothorax about twice as wide as base of head; mesothorax same size as prothorax in early instars but slightly narrower than mesothorax; abdominal segments 1 through 8 slightly narrower than metathorax; abdominal segment 9 approximately half as long as 8, hemispherical, evenly rounded at apex, with a small, vertical, slitlike, ventral anus. Pronotum (fig. 8) with anterior and posterior light buff transverse band composed of very minute, posteriorly directed asperities, with small triangular dark brown spot on each side of posterior band; mesonotum with transverse bands as on pronotum but triangular spots absent; metanotum and abdominal segments 1 through 8 with transverse bands but posterior band becoming much weaker and smaller on posterior segments. Prothorax laterally with small buff transverse band. Prosternum (fig. 7) with 3 buff transverse bands—a narrow anterior band interrupted medially by head, a wide middle band, and a moderately wide posterior band—with a long triangular dark brown spot on each side of middle band. Mesosternum and metasternum with middle and posterior transverse bands as on prosternum, anterior band absent. Abdominal sterna with middle transverse band only. Apex of 9th tergum with small light brown spot. Abdominal terga 2 through 7 and sterna 1 through 8 each with an areole on middle of posterior third; on terga posterior areoles much wider than long (width 1.6 times length), anterior areoles more nearly circular (width 1.3 times length); on sterna middle areoles much wider than long (width 1.6 times length), anterior and posterior areoles more nearly circular (width 1.3 times length); areoles composed of simple, thin, linear sclerotized circle or oval, without sclerotized central area. Spiracles (fig. 15) with thick, deep, posteriorly slanted peritreme, with biforous opening; mesothoracic spiracle below midheight of segment, large, length 1.7 times width; abdominal spiracles smaller, width approximately 0.75 width of mesothoracic spiracle.

The larva of *Dirrhagofarsus lewisi* is distinguished from other North American eucnemid larvae by the following combination of characteristics:

The absence of lateral teeth on the head capsule, the distribution of the areoles, and the absence of obvious asperities on the 9th abdominal segment.

Discussion of Larval Morphology

The most obvious characteristics of eucnemid larvae are in the mouthparts; the mandibles are unique. First, a discussion of the ordinary mandibles of beetle larvae is in order. Mandibles of all but a few beetle larvae (fig. 11) are subpyramidal or sickle shaped and pivot on a dorsal and a ventral point of articulation; the dorsal point is a short projection of the head capsule and a corresponding acetabulum (f2) on the dorsolateral corner of the posterior border of the mandible; the ventral point is an acetabulum on the head capsule and a corresponding knoblike projection (f1) on the ventrolateral corner of the posterior border of the mandible. Two muscles and their tendons close and open the mandibles; a large muscle (AD), the adductor, attached to the posteromedial border of the mandible just basad of the molar area closes the mandible; a small muscle (AB), the abductor, attached to the posterolateral border opens the mandible. The work of this kind of mandible, tearing and crushing, is, of course, done by the apicomedial teeth and the basomedial grinding area, the mola. Great force must, therefore, be transmitted apicomedially and medially, but, because of lack of resistance, only a small force is required to open the mandibles. The mandibles perform such movements very well. A physicist would say that this "machine" is a pair of levers of the second order having a great mechanical advantage (fig. 11); the distance (X) from the large exerted force (AD) to the fulcrum (f1, f2) is very great, and the distance (Y) from the fulcrum (f1, f2) to the transmitted force (AB) is very great (the transmitted force is, of course, applied to the apex and mola of the mandible by triangulation).

On the other hand, in larvae of *Dirrhagofarsus lewisi* (fig. 12) the exerted force of the mandibles is essentially outwardly directed, not medially directed; the mandibles cut and push wood fibers laterally. Their design is necessarily completely different than is usual in beetle larvae. First, the teeth are on the anterior border of the mandible near the body's midline. Second, the points of articulation are placed closer to the body's midline on the mandible; the dorsal point is a short process on the head capsule and a corresponding acetabulum (f2) on the dorsal midpoint of the posterior border of the mandible, and the ventral point is a short process on the head capsule and a corresponding small acetabulum (f1) on the ventral lateral third of the posterior border of the mandible. Third, the closing muscle (AD), the adductor, attached to the posteromedial border of the mandible is small, whereas the opening muscle (AB), the abductor, attached to the posterolateral border of the mandible is large. These mandibles are a "machine" composed of a pair of levers of the first order having a moderate mechanical advantage (fig. 12). The large exerted force (AB) is placed laterally and the distance (Y) from that force to the fulcrum (f1, f2) is large; however, the distance (X) from the fulcrum (f1, f2) to the transmitted force is slightly larger. It is obvious that because X is larger than Y in *Dirrhagofarsus*, the mechanical advantage is not so great as in mandibles of other groups. Perhaps the movement of head capsule points of articulation necessary for a more advantageous levering system is not easily accomplished in

evolution; perhaps the problem in *Dirrhagofarsus* was solved not by such movement of points of articulation but by extension of the base of the mandible laterally to increase distance Y. The levering system and muscles of these mandibles, as just described, together with the earlier mentioned position of the teeth and the asymmetrical points of articulation are efficient special adaptations for a unique method of cutting wood and feeding. The teeth are present on the ventral edge of the mandible only (fig. 14), and the slightly asymmetrical alignment of the points of articulation on each mandible allows a cutting action, not tearing or crushing, by moving the toothed ventral cutting edge slightly ahead of the rounded dorsal edge. The exact movements of the body and head have not been observed. However, one might infer from shape and articulations that the mandibles shear tiny fragments of damp wood from the sapwood, that these fragments are then pressed against the wall of the larval chamber by the rounded dorsal surface of the mandible, and that liquid is thereby squeezed from these fragments.

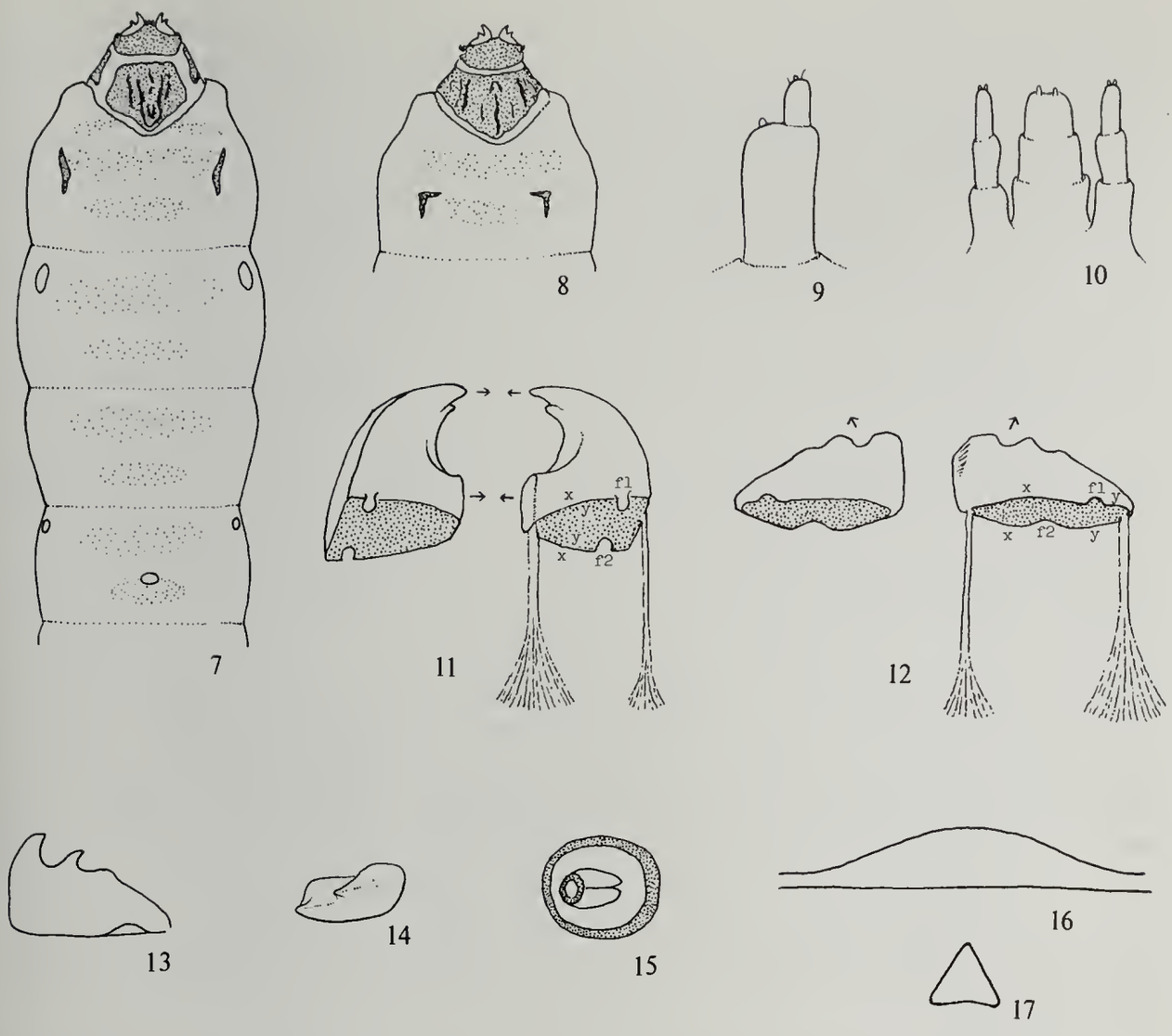
The digestive tract of the larva is a simple membranous tube except anteriorly. The tract in the head is sclerotized except at its attachment to the mouth frame; the relationship of the first part of the tract to the mouthparts remains obscure. The obvious part of the tract in the head (fig. 16) is a heavily sclerotized tube, slender anteriorly, expanded medially, slender posteriorly, and then becoming membranous as it leaves the head. The expanded medial part is triangular in cross section, with the ventral surface concave and lightly sclerotized (fig. 17). The function of this distinctive structure is unknown. Perhaps it is a pump to push digestive fluid out into the wood or a siphon to pull predigested fluids into the gut, or perhaps it is both.

All larval instars are similar except for body size and mandibular teeth. Perhaps lack of sharpness of the mandibular teeth in later instars is caused by wear. Mandibles are present in all instars, and the head is not dimorphic. Leiler (1976:20) clearly described the presence and absence of mandibles and the variation in head structures in different instars of *Eucnemis capucina* Arh. in Europe.

The oval structure on the posterior half of most abdominal terga and sterna was called the areole by most writers of French and English and the Hornplatte by Leiler (1976:12). The function of the areoles is unknown, but Sharp (1886:301) suggested that they might be supplementary organs of nutrition.

Life History

In addition to the initial collection of *Dirrhagofarsus lewisi* on 4-III-76, another sample of the wood was collected from the same beech tree on 5-V-76. At this time most of the larvae had pupated and adults from this material emerged 14-21-V-76. The first field-collected adult was found on the host tree on 1-VI-76. Soon after this capture, a band of tanglefoot was painted around the trunk about 3 m from the infested base and examined at least once each week to determine the length of adult activity. Specimens were most numerous in late June through July. The tree was observed until the end of August, and about 35 additional adults were found either in the tanglefoot or concealed in dark niches along the trunk. The last



Figs. 7-17. *Dirrhagofarsus lewisi*, larva: 7) anterior half, ventral view; 8) head and prothorax, dorsal view; 9) antenna; 10) labium, ventral view; 11) mandibles of non-eucnemid beetle larva for comparison, ventral view, f1—ventral articulating point, f2—dorsal articulating point, X and Y—distances from articulating points to muscles, AB—abductor muscle, AD—adductor muscle; 12) mandibles, late instar, ventral view, abbreviations as in fig. 11; 13) left mandible, early instar, ventral view; 14) left mandible, lateral view; 15) spiracle; 16) anterior part of digestive tract, lateral view; 17) same, cross section at middle length.

adult was found 11-VIII-76, indicating that adult activity likely ceases about the middle of August. Adults hiding during the day also suggested that the beetle is nocturnal.

Additional observations were made on *D. lewisi* by removing about 80 sq. cm. of bark from a portion of the trunk where fermentation was much less advanced than in the area where adults were emerging. The freshly exposed sapwood was then partially covered with some of the pieces of loose bark. During the day inactive adults were found hidden under the loose bark, but at night 8 adults were rapidly running about the exposed sapwood. It is apparent that mating and oviposition occur nocturnally, and that the preferred host is clean, wet sapwood of dead beech trees having a distinct odor of fermentation.

Field observations correlated with studies of specimens show a life history as follows: Eggs are deposited singly 6 to 25 mm apart from early

June to the middle of August in exposed sapwood of recently dead beech trees. Eggs are inserted 3 to 4 mm into the wood through a long needlelike ovipositor. In 10 to 15 days the larvae emerge and commence excavation of an oval chamber. Hollowing of the larval chamber is accomplished by rasping action against the wood cells by protruding mandibular teeth aided by additional rough projections on the dorsal, ventral, and lateral areas of the head. Possibly the first instar larva works in a linear position until the oval chamber is constructed, but all larvae (about 30 in all, some only 8 mm long) had assumed a U-shaped position in the chamber (fig. 6). Larvae removed from their chamber quickly assumed an orthosomatic position, and their length exceeded the length of the chamber; the larvae could be replaced only when bent back to the U-shape. Perhaps this phenomenon provides greater leverage in forcing the rasp laden head against the surrounding wood tissue. Due to the minute oral opening and reduced mouthparts, it is probable that nutrients must be ingested in a liquid form, but it is not clearly understood whether this is done by simply breaking down the surrounding wood cells and ingesting fermenting sap or by reducing cellulose material to liquid form by secretion of a digestive enzyme. Furthermore, the larval chamber is devoid of the fecal pellets or coarse frass that would result from ingestion of solid food. The only solid waste material is a wet, tightly packed, very fine sawdustlike material stored on two sides of the larval chamber. This material also contains the cast larval skins. Growth from egg to mature larva requires 10 to 11 months. The same larval chamber is used by the pupa; the pupal stage lasts 2 to 3 weeks. Adults have normal mandibles and chew their way 3 to 6 mm to the surface, leaving a round exit hole.

Remarkably, *D. lewisi* can develop from egg to adult in a small oval chamber with no visible entrance or exit holes, no waste needs to be expelled, and no evidence of the species' existence in the tree is seen until the adult emerges from a telltale exit hole. The cryptic habits and rather limited environmental niche may explain why the species has not been collected in the United States before 1976. On the other hand, the recent discovery might simply be because of a recent introduction.

Acknowledgments

Our thanks go to Dr. Antonio Cobos, Consejo Superior de Investigaciones Cientificas, Almeria, Spain, for comparing our specimens with closely related Dirhaginae; Dr. Rupert Wenzel and E. H. Smith for allowing us to study the holotype of *Dirhagus wrighti* Knull; Dr. S. Hisamatsu, Ehime University, Japan, for providing specimens of *Dirrhagofarsus lewisi* from Japan for comparison; J. F. Cavey who collected many adults and reported adult activity on the host tree during the summer; R. C. Gilbert, U.S. Customs Service, Chemistry Laboratory, Baltimore, Md., for photographs of the larva and genitalia; T. F. Hlavac for reading the manuscript; and Molly K. Ryan for helping with the illustration of the adult.

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—P.P.S.

SOCIETY NEWS

The Idaho Entomology Group.—The Idaho Entomology Group was started in 1974 as an informal association to bring together interested professional and amateur entomologists. Although intended for people within the state, 34 of the group's 88 members are from other states, ranging from Oregon to North Carolina. A monthly newsletter, detailing group activities such as field trips and meetings and other notes of interest, is sent to all members who have donated $3.00 annually for its printing and mailing. Current editor is Dr. Charles Baker, 5315 Belair, Boise, Idaho 83705. President is Dr. Robert Saunders, 3968 Summerset Way, Boise, Idaho 83705. Either may be contacted regarding membership or the newsletter.

—G. A. Shook, W. H. Clark

NOTICE OF MEETING

A joint meeting of the Idaho Entomology Group, the Washington State Entomological Society and the Oregon Entomological Society will be held April 14, 1979, at the College of Idaho, Caldwell, Idaho, in the Boone Science Hall. Field trips will be scheduled for Friday the 13th and Sunday the 15th, weather permitting. The entomology collection of the College's Museum of Natural History will be available for work or visitation. Interested persons may contact Bill Clark, 6305 Kirkwood Rd., Boise, Idaho 83705 for further information.

—W. H. Clark, G. A. Shook